**\*\*\*All bone growth is appositional**

|  |  |  |  |
| --- | --- | --- | --- |
| **CELLS** | **DESCRIPTION/LOCATION** | **STRUCTURE** | **FUNCTION** |
| **Osteocyte** |  |  |  |
| **Osteoblast** | * Immature cell * Not cap * able of cell division   LOCATION:   * Found on existing bone surfaces | * Cuboidal * Dark or basophilic, closely packed together * Cellular processes connect to adjacent cells early on * Mineralized matrix will eventually completely surround cell | * Actively laying down bone matrix on the existing surface |
| **Osteoclast** | * Large, multinucleated cell (2-70 nuclei) * Under influence of PTH and calcitonin   LOCATION: | LM LEVEL:   * Striated border * Located in ECM * Ground substance and mineral eroded away, leaving only collagen fibers * anhydrase in vesicles * Produce H+ ions, pumped outside of | * Active bone resorption * Dissolve away bone matrix to form depression cell sits in * With continued action may form tunnels in bone |
| **Osteoprogenitor cells** | * Reserve mesenchymal cells or peri * cytes * Undifferentiated cells | * Unable to identify * Until they begin to differentiate into osteoblasts, we can NOT identify them | * Differentiate into osteolasts |
| **Bone lining cells** | * Line all bone surfaces   LOCATION: | * Forms interconnecting network w/ other | * Maintains microenvironment in bone tissue * Separates bone tissue from other tissue (e.g. bone |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EXTRACELLULAR MATRIX** | | | | | |
| Organic + inorganic components form structural material that is quite strong but also flexible enough not to be brittle. | | | | | |
| **ORGANIC MATRIX**  25-30% of ECM | | | **INORGANIC MATRIX**  60-65% of ECM | | |
| * Great **strength** of **collagen fibers** * **Flexible** * Only organic matrix, can tie bone in a knot | | | * Great **strength** of **mineral** * **Brittle** * Only inorganic matrix, brittle like china | | |
| **Collagen Fibers**  90-95% of organic matrix | **Ground Substance**  Scant amount  Does NOT contain much water | | **Ions** | **Hydroxyapatite Crystals** | **Hydration Shell** |
|  | **Proteoglycans** | **Glycoproteins** | * *Typical ions*   CaPO, CaCO4, Mg, F, citrate   * *Trace ions*   Fe, Zn, Cu, Pb, Al, Sr, etc. | * Ions are in crystal form * Needle shape * Aligned parallel to collagen fibers * ) | Water associated (surrounds) each crystal |
| Form of aggrecan | 1.*Osteonectin*  Binds plasma membrane to collagen fibers (matrix)  2.*Osteocalcin*  Binds calcium to matrix  3*.Bone sialoprotein* |

|  |  |
| --- | --- |
| **EXTRACELLULAR FIBERS** | |
| Bone tissue is classified by *arrangement* of collagen fibers | |
| **Collagen Type 1** | |
| * Primary fiber found in bone * Densely packed   + Laid down in layers, fibers all run parallel in a single direction   + Fibers arranged in alternating layers w/ fiber direction at right angles to preceding layer   + Arranged like layering of plywood   + Can see arrangement ONLY w/ **polarized light**   ach individual layer is a **lamellae** | |
| **Woven Bone** | **Lamellar Bone** |
| **Woven bone = immature bone = primary bone** | **Lamellar bone = mature bone = secondary bone** |
| NO layered collaged fibers  RANDOM orientation of *bundles* of collagen fibers running in *all directions* | *Layered* arrangement of collagen fibers |
| Start with woven bone, convert to lamellar  STRENGTH: lamellar > woven | |

|  |  |
| --- | --- |
| **TYPES OF BONE TISSUE** | |
| **TRABECULAR** | **CORTICAL** |
| Located *inside* of bone | Consists of *outer layer* of bone |
| **Cancellous** or **spongy** bone | **Dense** or **compact** bone |
| *More space* than bone tissue per unit volume | *More bone tissue* than space per unit volume |

|  |  |
| --- | --- |
| **TRABECULAR BONE** | |
| **Structure/Morphology** | **Function** |
| **TRABECULA/SPICULES**  Composed of thin processes/fingers of bone tissue called ***trabecula*** or ***spicules***  Trabecula are made up of ***trabecular packets***   * Trabecular packets – angular shaped parcels Packet(arrangement | Packets fit together to form the trabecula  Gets nutrients from surface, BV of central canal  Moved from blood supply, grown away and laid down the osteon to receive nutrients from greater distance |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **CORTICAL BONE** | | | | |
| **Structure** | **Morphology** | | | **Function** |
| **Osteon = Haversian system** | * Basic structural unit * Contains concentric layers of collagen fibers and osteocytes (4-20 | **Central canal (Haversian canal)** | | Deliver nutrients |
| **Cement line** | |
| **Volkmann canals** | * Contain diagonally running BVs * *Lack of concentric layers* of cells around them | | | Supply blood to vessels in osteons |
| **Interstitial lamellae** | * Remnants of older osteons that have been partially removed * Part of osteon w/o its central canal | | |  |
| **Outer circumferential lamellae** | * Layers of bone (osteocytes) that *run all the way around outside of bone* * Laid down by the *periosteum* | | | Bind bone together  Helps hold all osteons in place |
| **Inner circumferential lamellae** | * Layers of bone (osteocytes) that *run all the way around inner surface of bone* next to marrow cavity * Not as prominent as outer circ. lamellae bc fewer layers on inside * Laid down by *endosteum* | | |  |
| **Periosteum** | outside of bone tissue on all bones | | **Fibrous layer**   * Outer layer   Vascular | Lays down outer circumferential lamellae |
| **Osteogenic layer**   * Inner most layer * Contains osteoblasts | Osteoblasts lay down mew bone (appositional growth) |
| **Sharpey’s fibers** | * Bundles of collagen fibers extending in from periosteum to be embedded in bone matrix (outer circumferential lamellae) * Located where muscle-tendon r ligaments attach to bone | | | Embed into bone matrix |
| **Endosteum** | * Single layer of cells lining inner layer of bone adjacent to marrow cavity * Looks like | | | Lays down inner circ. lamellae |

|  |  |  |
| --- | --- | --- |
| **SHAPE** | **DESCRIPTION/EXAMPLES** | |
| ***Long bones*** | Humerus, ulna, femur, tibia, fibula, phalanges | |
| ***Short bones*** | Carpal, tarsal | |
| ***Irregular bones*** | Vertebrae, hip, facial | |
| ***Flat bones*** | Skull – frontal, parietal  Curves | **Diploe**  This is the layer of trabecular bone btwn two layers of compact bone |
| **Inner & Outer tableau**  These are the layer of dense bone on the inside and outside of the flat bones in the skull |
| ***Sesamoid bones*** | Patella, pisiform | Bones formed within a tendon of a muscle |

|  |  |
| --- | --- |
| **GROSS STRUCTURE** | **DESCRIPTION** |
| ***Epiphysis*** | The enlarged area at each end of a long bone |
| ***Diaphysis*** | The shaft of a long bone |
| ***Metaphysis*** | The cone shaped region connecting the epiphysis with the diaphysis |
| ***Epiphyseal plate*** | The cartilage region found in the metaphysic  Responsible for increasing length of bone |

|  |  |  |  |
| --- | --- | --- | --- |
| **FUNCTIONS OF BONE TISSUE** | | | |
| **STRUCTURAL SUPPORT** | | **RESERVOIR FOR MINERAL IONS** | |
| *Structural bone*  *Mature osteons* and *interstitial lamellae*  Heavily calcified bone | | *Metabolic bone* | |
| **Morphology**   * Inorganic salts impregnated in organic matrix * Rigidity and strength | **Function**   * Maintains shape and form of body * Protects soft tissues | **Description**   * Not quite dead * Alive and dynamic * Continually removed and rebuilt or remodeled | **Function**   * Reservoir of mineral ions for rest of body * Release ions from inorganic matrix via internal remodeling |

1. List and describe the theories of mineralization (calcification) of bone matrix.

**Mineralization (calcification) process**

How does the unmineralized bone matrix (osteoid) become mineralized?

***Calcification*** – deposition of Ca salt (mineral – hypoxyapatite crystals) in tissue (any tissue – cartilage, CT, or fat tissue)

**Mineralization in bone**

**Two phase process**

1. ***Primary mineralization***
2. ***Secondary mineralization***

**Theories of how mineral is deposited**

|  |
| --- |
| **THEORIES OF MINERALIZATION** |
| **CELLULAR NUCLEATION THEORY**  Matrix vesicles initiate calcification |
| **Matrix Vesicles**  Small blebs of cytoplasm pinched off from cells |
| Location:   * Seen in calcifying cartilage   Contain:   * **Alkaline phosphatase**   Mode of calcification:   * Tissues that do NOT undergo calcification **normally** numerous inhibitors of calcification: PPi, nucleotides, citrates, Mg * **AP increases Ca and PO** levels by **inhibiting PPi**, and inhibitor   Accumulate:   * Ca   Mode of calcification:   * Ca receptors on membrane surface * Alternates w/ PO receptors   Alternate spacing of R on memb help form crystals |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **THEORIES OF MINERALIZATION** | | | | |
| **MACROMOLECULAR NUCLEATION THEORY**  Four different macromolecules implicated | | | | |
| **Sulfated proteoglycans**  Undergo conformational change | **Collagen fibers**  Heterogeneous nucleation | **Glycoproteins**  Different pattern of mineralization compared to fibrils | | **Coumadin**  Drug – prevents clotting by interfering w/ carboxylation of glutamic acid |
| **Osteocalcin** | **Chondrocalcin** |
| Mode of calcification:   * Normally hold Ca * During calcification, modified and release sequestered Ca * Associated w/ PO | Location:   * Collagen fibrils   Mode of calcification:   * Gap region btwn tropocollagen molecules initiates   Note: 50% of crystals in bone are in gaps | Location:   * Ground substance of cartilage * Diffuse distribution throughout matrix   Mode of calcification:   * Binds Ca * Initiates mineralization * Both build up in matrix just prior to mineralization | | Mode of calcification:   * Side effect interferes w/ synthesis of osteocalcin * Prevents Ca deposition   Note: Long term **warfin** therapy, severe bone disorders (take Ca supplements) |

PROCESS:

|  |
| --- |
| **Formation of osteoclasts**  Granulocyte-macrophage progenitor cells migrate out of BV at appropriate location  Fuse together to form osteoclasts  **Resorption Cone (Resorption cavity, tunnel)**  ORIGIN: osteoclasts in dense bone  Cavities become tapered as they enlarge  CHARACTERIZATION:  *Large lumen* in bone matrix w/ osteoclasts lining it  Us *not in the center* of an os*No circumferential layers* of osteocyte that run entirely around large central canal  PROCESS: Region w  here osteoclasts are actively removing bone matrix  RESULT: releas  e of Ca and other ions into blood  **Reversal zone**  PROCESS:  No longer any bone resorption and bone deposition has not begun  Macrophages scavenge debris and smooth out surface  **Closing cone or forming osteon**  PROCESS:  See chart below. Progression is repeated until entirely new osteon is completed  CHARACTERIZATION OF RESULT:  Forming osteon has a *large central canal*  Only *a few circumferential layers* of osteocytes present  RESULT:  creates generations ofnants of partially removed osteons are **interstitial lamellae** |

**CLOSING CONE/FORMING OSTEON:**

|  |  |  |
| --- | --- | --- |
|  | **PARATHYROID HORMONE** | **CALCITONIN** |
| **Secreted** | *Low* peripheral blood Ca level | *High* blood Ca level |
| **Receptors** | Osteo*blasts*   * Secrete **Osteoclastic Stimulating Factor** | Osteo*clasts* |
| **Action** | Stimulates osteo*clasts* to *increase resorption* activity by   1. Removing bone matrix and releasing Ca 2. *Decreasing osteoblastic activity* so bone matrix not being laid down rapidly | *Decreases osteoclastic* activity  *Increases osteoblastic* activity and *deposits Ca* |
| **Net Effect** | *Increase* blood Ca level | *Decrease* blood Ca level |

Rates of bone turnover:

* Compact bone internal remodeling – 3%/year
* Trabecular – 26%/year
* Each individual bone and various parts of each bone have different turnover rates
* About 7.6% of all bone in body turns over/year
* Every 12-15 years new skeleton
* Internal remodeling goes from birth til death
* Replaces woven with lamellar in dense or trabecular bone

|  |  |
| --- | --- |
| **MORPHOLOGY of TRABECULAR BONE** | **TRABECULAR REMODELING** |
| * Trabecula are composed of mosaic of trabecular packets * Each packet is lamellar bone * Each trabeculae undergoes periodic replacement | * Like internal remodeling * Uses osteoclasts to scoop out cavity where new packet will form   + Pit is gouged out of trabecular surface by osteoclasts   + Filled in by osteoblasts one layer at a time   + Faster than internal remodeling in cortical bone |